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(54) METHODS AND APPARATUS EMPLOYING PERMANENT MAGNETS FOR MARKING, LOCATING, TRACING AND IDENTIFYING HIDDEN OBJECTS SUCH AS BURIED FIBER OPTIC CABLES.

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Description

Background of the Invention

This invention relates to a method and an apparatus in which permanent magnets are employed to mark hidden objects so that the objects may be located, traced, and identified. The invention has particular application to buried fiber optic cables and to other buried non-conductive objects, such as ducts, conduits, or pipes used by utilities. The invention will be d scribed, for purposes of illustration only, as applied to ducts for fiber optic cables.

Many of the fiber optic cables currently being placed in the ground are totally non-conductive. Even the strength member is non-metallic. Conductors that might be used for tracing a buried cable are omitted to prevent lightning from following the conductors and damaging the cable. The absence of conductors creates problems when it becomes necessary to locate a buried cable, because cable tracers require a conductor that carries a tracing signal.

It has previously been proposed to associate permanent magnets with a fiber optic cable, as by providing the magnets on a tracer tape buried separately along with the cable, in order to assist in locating and tracing the cable. However, this approach has several disadvantages, including the possibility that the tracer tape will be installed improperly and thus not detected, the limited distance at which the tape can be detected, and the inability reliably to distinguish the weak magnetic field of the magnets from magnetic fields associated with ferrous pipes, for example, that may be buried in the same area.

JP 60-82881, on which the preambles of claims 1 and 21 are based, discloses an underground piping, which is made from ferrite-blended synthetic resin and magnetized by a magnetizer. The location of the piping can be detected by detecting the magnetic field from the magnetized piping.

This prior-art method cannot be used for identifying different buried objects.

EP-A-0 011 536 discloses a warning device, comprised of a plastic grid, which is to be placed above a buried elongate object. To make it possible to detect the object, a magnetic powder is incorporated into the plastic. The powder is magnetized to provide a uniform and constant magnetic field over the total length of the grid.

According to EP-A-0 011 536, the intensity of the magnetic field can be varied within certain limits by varying the proportion of magnetic material included in the plastic. However, the magn tic field is still uniform and constant for a specific object, and the intensity only varies between different objects. Since the intensity of the magnetic field diminishes with the distance and since thus two objects buried on different depths and including different proportions of magnetic materials may produce the same magnetic field intensity at ground level this technique can only be used for identification purposes in those cases where the depths to the different objects are known.

Other examples of methods and apparatus for detecting buried elongate objects are disclosed in US-A-3 568 626, US-A-2 854 840, US-Re. 30 393, JP-A-1-54 280 and DE-A-3 106 661. None of these methods and apparatus makes the identification of different buried objects possible.

Brief Description of the Invention

The present invention provides a new method and a new apparatus for marking, locating, tracing, and identifying hidden objects, such as buried, non-conductive cables (e.g., fiber optic cables) and non-conductive pipes, tubes, ducts and conduits. The method and the apparatus have the features recited in claim 1 and 21, respectively.

In accordance with one of the broader aspects of the invention, an elongated permanent magnet device is provided on an elongated hidden object to be detected, with the length of the device extending along the length of the object. The device is formed of a magnetic material dispersed in said object. The magnetic material is magnetized transversely of said object to provide a magnetic axis transverse to the length of the object and to provide a magnetic field that varies in a predetermined manner along the length of the object. The hidden object is detected by detecting the variations of the magnetic field, the strength of which may diminish substantially as the square of the distance from the device along a direction transverse to the length of the object. The elongated permanent magnet device may comprise a strip having a width dimension substantially greater than its thickness dimension, the strip being magnetized in the direction of its width. The strip may be formed into a helix. With such a device, the orientation of the magnetic axis varies at different positions along the length of the object to provide a magnetic field signature for identifying the object.

Furthermore, the device may produce a magnetic field having a predetermined magnetic field signature including a series of peaks and valleys at points along a line substantially parallel to the length of the object; The magnetic field detector may be moved along the line and then produces an output from the detector corresponding to the peaks and valleys.

Brief Description of the Drawings

The invention will be further described in conjunction with th accompanying drawings, which illustrate preferred (best mode) embodiments of the invention, and wherein:

Fig. 1 is a diagrammatic perspective view illus-

trating an underlying principle of a first embodiment of the invention;

Fig. 2 is a diagrammatic perspective view illustrating one application of the invention, namely locating and tracing a fiber optic cable;

Figs. 3A and 3B are fragmentary diagrammatic perspective views illustrating structural variations of the first embodiment, while Figs. 3C and 3D are corresponding end views, respectively;

Fig. 4 is a diagram illustrating a magnetic field signature produced in accordance with the first embodiment of the invention;

Figs. 5-9 are fragmentary diagrammatic perspective views illustrating further structural variations of the first embodiment.

Detailed Description of Preferred Embodiments

Before the invention is described in detail, certain aspects of permanent magnets will be considered.

An ordinary bar magnet has a magnetic field that is a maximum near its poles. If the magnet is oriented with its longitudinal axis (magnetic axis) vertical, for example, a magnetic field vector measuring device will produce a response if the sensory axis of the device is oriented vertically over the magnet. If the magnet is then turned 90°, so that its longitudinal axis is horizontal, the response will drop substantially to zero as the magnetic vector becomes perpendicular to the s nsory axis of the measuring device. If the magnet is turned 90° again, so that it is inverted from its initial position, the measuring device will produce a response of opposite polarity from the initial response. Turning the magnet further by 90° produces a zero response again. Finally, turning the magnet 90° again places the magnet in its initial position and produces the initial response of the measuring device.

It is known that for a given pole strength, the longer the magnet, the stronger the field that will be det cted by the measuring device, and as noted earlier, it is known that the maximum field lies off of the end of the magnet. However, except as explained hereinafter, the detected magnetic field strength of a bar magnet is a function of the inverse cube of the distance from the magnet, that is, it diminishes with the cube of the distance from the magnet, so that doubling the distance causes an eight-fold loss of field. See Ferromagnetism by Bozorth, Van Nostrand Company, Chapter 19, p. 838. Therefore, even if the sensory axis of the measuring device is aligned with the l ngth of the-magnet, and even if the length of the magnet is made as long as possible within practical constraints, the distance at which the magnet can be reliably detected by a practical magnetic field measuring device is quite limited.

In accordance with on aspect of a first embodiment f the present invention, a hidden object to be d tected has associated therewith a permanent magnet identifier device having a magnetic field that diminishes as the square of the distance from the device, rather than as the cube of the distance, as is usually the case. To maximize th detection range, the identifier device may be constructed and disposed so as to provide a substantial vertical component of magnetic field for detection by a magnetic field detector that produces a strong response to that component. The identifier device is preferably an elongated strip that is magnetized in the direction of its width (perpendicular to its thickness) to provide a magnetic axis in the direction of the width. By virtue of this construction, if the width of the strip is maintained vertical, the detected magnetic field is essentially the sum of the magnetic fields of an infinite series of bar magnets. The relationship between the magnetic field and the distance from the strip is then governed by an inverse square law, so that doubling of the distance causes a four-times loss of field, rather than an eight-times loss as in the case of a discrete bar magnet.

There are a few instances in the prior art in which the relationship between the magnetic field of a permanent magnet and the distance from the magnet is governed by an inverse square law. For example, if the magnetic field is measured in the vicinity of one pole of a very long bar magnet at a position so far from the opposite pole that the contribution from the opposite pole is negligible, then an inverse square law applies. However, such instances have little relevance to the use of permanent magnets in locating, tracing, and identifying buried elongated objects such as ducts or pipes that extend generally horizontally. Prior art techniques for magnetically marking such objects so that they may be located and traced have not been able to provide the advantages of the present invention, including, in the first embodiment, a relationship between the magnetic field and the distance from a permanent magnet identifier device that is governed by an inverse square law.

While in some cases it may be possible to maintain vertical orientation of the magnetic axis of the identifier device of the invention, in many cases this is not possible as a practical matter. For exampl , if a straight strip magnetized width-wise is attached to a duct so that it extends lengthwise along the length of the duct at one side thereof, it is difficult to ensure that the width of the strip will be vertical when the duct is buried. However, as will be explained hereinafter, if there is a sufficient length of the strip that remains essentially vertical, detection of the strip will follow the inverse square law, as desired.

In accordance with an important aspect of the first embodiment of the invention, it is not necessary to maintain a vertical orientation of the width of the strip throughout its length. T the contrary, the strip is preferably formed into an elongated helix having a longitudinal pitch (axial length of each turn) that is

substantially greater than the cross dimensions of the helix, so that the width of the strip along a substantial portion of the length of each turn of the helix will be oriented essentially vertically. The helical configuration has an important additional advantage in that a distinctive "magnetic field signature" is produced that will be detected by a magnetic field detector to confirm the identification of the magnetic strip. In practice, a pitch of about twelve feet has been found quite satisfactory where the inverse square law effect is desired.

Referring now to the drawings, Fig. 1 illustrates a portion of a magnetic strip 10 with its length L extending horizontally and its width W extending vertically. The width dimension of the strip is much greater than the thickness T of the strip, and the strip is permanently magnetized along its width W, so as to provide a magnetic axis in the direction of the width and so as to maximize the vertical magnetic field component detected at a measurement point at a distance "r" from the longitudinal center line of the strip. In Fig. 1 the measurement point is shown in the plane of maximum field. As is apparent, the magnetic field seen at the measurement point is, in effect, the sum of the magnetic fields of an infinitely long series of permanent magnets with their magnetic axes oriented vertically (in the direction of the width W of strip 10).

The strip may be a magnetic tape 1.3 cm (1/2 in.) wide and 1.6 mm (1/16 in.) thick, for example, and may be formed of a mixture of rubber or plastic and a ferrite such as barium ferrite, for example. Such strips, comprising 80% by weight or 65% by volume of magnetic powder (such as barium ferrite and perhaps some strontium) and the balance rubber, are used in the magnetic gaskets of refrigerator doors, but, in general, they are not magnetized in the direction of the width of the strip as shown in Fig. 1.

As shown in Fig. 2, the strip 10 of Fig. 1 is supported on an elongated, non-conductive object 12, such as a fiber optic cable, tube, pipe, or duct, for example. In the form illustrated, the strip is wound about the object 12 to form a long-pitch helix 3.7 m (12-foot) pitch, for example) so that the axis of the helix extends along the length of the object 12. The strip may be wound about a fiber optic cable, for example, or about a conduit or duct in which the cable is contained. The strip may be adhered to the object by tape or adhesive, for example.

Instead of providing a separate strip that is attached to an object, a magnetic strip may be painted on or coated on the object, or may be extruded into or molded into the outer surface of the object (or the inn r surface if the object is hollow). If the object is formed of plastic, a ferrite may be mixed directly into a plastic resin or binder before extrusion or molding of an object. If the ferrite is dispersed throughout the object, it may still be magnetized so as to form a helical strip with a magnetic axis in the direction of its width. The term "strip" is therefore intended to include what might be termed a "stripe." Figs. 3A and 3C illustrate a structural variation including such a stripe 10' that is integral with an elongated object 12'. Figs. 3B and 3D illustrate a further variation including a pair of such stripes, 10", 10'" integral with an elongated object 12". In this variation the orientation of the magnetic axis N-S "rotates" in successive transverse planes along the length of the object, simulating a diametral strip that is twisted about its longitudinal axis. This variation is also illustrative of the fact that the identifier device may include more than one strip or stripe. In all variations of the first embodiment th magnetic axis of the identifier device is transverse to the length of the object.

To detect a buried object associated with a magnetic identifier device in accordance with the invention, a magnetic field measuring device or gradiometer 14 may be employed as shown in Fig. 2. All such devices are embraced within the term "magnetic field detector" as used herein. The model GA-52B magnetic locator of the assignee of the invention, having a detection threshold of about 10 gammas, has been employed quite successfully for this purpose. Maximum detection distance is about 1.8 m (6 feet) for the strip of Fig. 2 (3.7 m (12-foot) pitch). The maximum detection distance varies with the pitch of the helix, so that a pitch of 6.1 or 9.1 m (20 or 30 feet)(or more) may be used to permit detection at greater distances when appropriate.

A unique magnetic field signature produced in accordance with the first embodiment of the invention is shown in Fig. 4 and comprises a series of positive and negative excursions (peaks and valleys). The magnetic field signature shown is a response curve of a vertical gradiometer, in which the ordinate represents the gradient field in gammas and the abscissa represents the distance in feet as the gradiometer is moved over the ground along the length of a plastic pipe buried thirty inches and provided with a permanent magnet identifier device as shown in Fig. 2. This signature is produced by the helical winding of the strip (which causes the orientation of the magnetic field to vary), and is quite useful in confirming the identification of the buried object and in distinguishing the object from other objects, such as ferrous gas and water pipes, that produce random positive and negative excursions. Initial detection of an identifier device in accordance with the invention may be accomplished by a "sweep" of the area where the identifier device ought to be located, using the magnetic detector 14 in a conventional manner. When a response is noted at different points indicating the general dir ction of an identifier device, confirmation of the id ntification is achieved by moving the magnetic detector along the length of the identifier device and noting the magnetic field signature.

By virtue of the invention, non-conductive buried objects, such as fiber optic cables, are located, traced, and identified at substantial distances, easily and reliably. The invention is economical to impl - ment and is therefore practical. Since th magnetic strip employed in the invention is non-conductive, lightning is no longer a problem. The strip is inert and stable and should last indefinitely in the ground. If the strip is cut, as by earth digging equipment, detectability of the strip is essentially unaffected, and the object associated with the strip can still be located. If the strip is integrated into or attached to the object during manufacture of the object, incorrect installation is no longer a problem. Also, use of the magnetic strip of the invention does not preclude the use of other locating means as well. The strip will not interfere with electronic markers, for example, or with a conventional wire or conductive tape placed above a cable in a trench.

Figs. 5-9 illustrate other structural variations of the first embodiment of the invention. In Fig. 5 an elongated hollow object 12 is provided with a plurality of straight magnetic strips 16 with their length parallel to the length of the object. The strips are spaced circumferentially of the object and may be provided on the outer surface or the inner surface of the object or within the material of the object. Each strip is magnetized to provide a magnetic axis in the direction of its width (transverse to the length of the object) at spaced locations along the length of the object. The pattern of magnetization is progressive, so that the orientation of the magnetic axis of the elongated magnetic identifier device constituted by the strips "rotates" from position to position along the length of the object. In the structure shown in Fig. 6 the strips, which in Fig. 5 extend along the entire length of the object, have been shortened to provide individual magnetized segments 17.

In Fig. 7 tubes 18 of magnetic material are provided at spaced locations along the length of the object. The tubes, which together constitute an elongated magnetic identifier device, are magnetized transversely of the length of the object, and the orientation of the magnetic axis shifts from tube to tube successively along the length of the object so as to "rotate."

In Fig. 8 the tubes of Fig. 7 are replaced by short-pitch helical strips 20 magnetized like the tubes of Fig. 7. Together, the strips constitute an elongated magnetic identifier device. If the turns of the strips are close enough, essentially continuous tubes of the type shown in Fig. 7 are defined.

In Fig. 9 a helical strip 22 similar to that of Fig. 3A is employed, but the helical strip has a short retrace 24 at successive positions along the length of the object (only one retrace being illustrated).

In the first embodiment of the invention a magnetic field signature comprising successive peaks and valleys of the vertical magnetic field component (or the horizontal field component) is obtained by virtue of the fact that th orientation of the magnetic axis of the identifier device, which is transverse to the length of the object, varies along the length of the object.

While preferred embodiments of th invention have been shown and described, it will be apparent to those skilled in the art that changes can be made in these embodiments without departing from the scope as defined in the appended claims. For example, although a standard vertical gradiometer may be employed as a magnetic field detector in accordance with the invention, a specialized magnetic field detector may also be employed. Such a detector may be designed to discriminate against signals other than the signal from the magnetic strip. Thus, AC signals may be filtered out. The magnetic field detector may have a readout display in which peaks and valleys of the magnetic field signature produce opposite polarity indications, such as left and right excursions of the needle of a meter from a center neutral position. The detector may be designed to respond to horizontal components of the magnetic field as well as to vertical components. If vector addition is performed on the vertical and horizontal signal components, then a vector sum may be displayed on a 360° compass-type display which rotates as the operator walks along the cable. The detection scheme may give a cable or conduit manufacturer, for example, the option of coding his product with a right hand or left hand helix. The scalar sum of the vertical and horizontal signal components may be indicated by an audio output which exhibits a maximum directly over a buried cable regardless of whether the operator is over a location on the cable where the magnetization is vertical or horizontal. It is evident that visual or audible displays, or a combination of both, may be used in accordance with the invention. Finally, the invention is not limit d to use with elongated objects that are buried under the ground; it may be employed to detect elongated objects that are otherwise hidden, such as sub-sea objects.

Claims

1. A method of detecting the location of a hidden elongated cylindrical or tubular object (12), in which said object is provided with an elongated permanent magnet device (10) having its length extending along the length of said object, said device is formed of magnetic material dispersed in said obj ct and th location of said object is detected with a magnetic field detector (14), characterized in that the magnetic material is magnetized transversely of said object to provide a magnetic axis transverse to the length of said object and to provide a magnetic field that varies in a

predetermined manner along the length of said object, and that the location of said object is detected by detecting the variations of said magnetic field with said detector.

2. A method in accordance with Claim 1, characterized in that said magnetic axis varies in orientation at different positions along the length of said object.

3. A method in accordance with Claim 1, characterized in that said magnetic field varies repetitively along the length of said object, and said detector detects the repetitive variations of said magnetic field.

4. A method in accordance with Claim 3, wherein said object is buried approximately horizontally beneath the surface of the earth and characterized in that detector is moved over the surface of the earth along a line approximately parallel to the length of said object in order to trace the location of said object.

5. A method in accordance with Claim 4, characterized in that the repetitive variations of said magnetic field produce a series of magnetic field peaks and valleys along said line that are detected by said detector.

6. A method in accordance with Claim 5, characterized in that said detector is of a type having opposite polarity indications corresponding to said peaks and valleys, respectively.

7. A method in accordance with Claim 1, characterized in that both horizontal and vertical components of said magnetic field vary repetitively along the length of said object.

8. A method in accordance with Claim 7, characterized in that said detector detects both said horizontal and vertical components.

9. A method in accordance with Claim 8, characterized in that said detector determines a vector sum of said horizontal and vertical components.

10. A method in accordance with Claim 8, characterized in that said detector determines a scalar sum of said horizontal and vertical components.

11. A method in accordance with Claim 1, characterized in that said detector is a hand-held gradiometer.

12. A method in accordanc with Claim 1, characterized in that said devic is formed as a helix having a longitudinal axis extending along the length of said object.

13. A method in accordance with Claim 12, characterized in that the longitudinal pitch of said helix is substantially greater than the cross dimensions of said helix.

14. A method in accordance with Claim 13, characterized in that said pitch is of the order of 3.66 m (12 feet).

15. A method in accordance with Claim 1, characterized in that said device is formed so that it has a width dimension substantially greater than a thickness dimension and is magnetized in the direction of its width.

16. A method in accordance with Claim 1, characterized in that said magnetic material is substantially non-conductive.

17. A method in accordance with Claim 1, characterized in that said object is formed of plastic.

18. A method in accordance with Claim 1, characterized in that said object is formed as a tube with the magnetic material dispersed in a wall of the tube.

19. A method in accordance with Claim 1, characterized in that the orientation of said magnetic axis is substantially vertical at regions spaced along the length of said object, and a vertical component of said magnetic field at said regions diminishes at a rate that is substantially less than th cube of the distance from said object in a vertical direction.

20. A method in accordance with Claim 19, characterized in that said rate is substantially the square of said distance.

21. An elongated magnetic device (10) for magnetically detecting the location of a hidden elongated cylindrical or tubular object (12), said device comprising magnetic material dispersed in said object, characterized in that the magnetic material is magnetized transverse to the length of the object so as to have a magnetic axis transverse to its length and so as to provide a magnetic field that varies repetitively along the length of the object in a predetermined manner, thereby to provide a characteristic magnetic field signature capable of detection by a magnetic field detector (14) moved along the length of the object, whereby the location of said object may be detected.

22. An elongated magnetic device in accordance with Claim 21, characterized in that the orientation of said magnetic axis varies repetitively along the length of the object.

23. An elongated magnetic device in accordance with Claim 21, characterized in that the magnetized magnetic material forms a strip in the shape of an elongated helix.

24. An elongated magnetic device in accordance with Claim 23, characterized in that said strip is substantially non-conductive.

25. An elongated magnetic device in accordance with Claim 23, characterized in that said helix has a longitudinal pitch that is substantially greater than the cross-dimensions of said helix.

26. An elongated magnetic device in accordance with Claim 25, characterized in that said pitch is of the order of 3.66 m (12 feet).

27. An elongated magnetic device in accordance with Claim 23, characterized in that the width of said strip is less than the width of said object.

28. An elongated magnetic device in accordance with Claim 23, characterized in that the width of said strip corresponds to the width of said object.

29. An elongated magnetic device in accordance with Claim 21, characterized in that said device comprises a plurality of spaced strips (16 or 17) of magnetic material with their length extending along the length of said object and being magnetized transverse to their length.

30. An elongated magnetic device in accordance with Claim 21, characterized in that said device comprises a plurality of spaced tubes (18 or 20) of magnetic material coaxial with the object and magnetized transverse to their length.

31. An elongated magnetic device in accordance with Claim 21, characterized in that said device comprises a plurality of strips (16 or 17) of magnetic material with their length extending along the length of said object at circumferentially spaced positions on said object and magnetized transverse to their length.

32. An elongated magnetic device in accordance with Claim 31, characterized in that said positions are also spaced longitudinally on said object.

33. An elongated magnetic device in accordance with Claim 21, characterized in that said device comprises a plurality of tubes (18 or 20) of magnetic material spaced along the length of said object and having collinear axes parallel to the length of said object, each tube having a magnetic axis transverse to the length of said object, and the magnetic axes of successive tubes having different orientations.

34. An elongated magnetic device in accordance with Claim 33, characterized in that each tube is defined by a helical strip (20).

Patentansprüche

1. Verfahren zum Ermitteln der Lage eines verborgenen länglichen zylindrischen oder röhrenförmigen Gegenstandes (12), wobei der Gegenstand mit einer länglichen, Permanentmagnetvorrichtung (10) versehen ist, deren Länge sich über die Länge des Gegenstandes erstreckt, wobei die Vorrichtung aus magnetischem Material besteht, das in dem Gegenstand verteilt ist, und die Lage des Gegenstandes mit einem Magnetfelddetektor (14) ermittelt wird, **dadurch gekennzeichnet,** daß das magnetische Material quer zu dem Gegenstand magnetisiert ist, so daß eine Magnetachse quer zur Länge des Gegenstandes geschaffen wird und ein Magnetfeld geschaffen wird, das über die Länge des Gegenstandes auf vorgegebene Weise schwankt, und daß die Lage des Gegenstandes ermittelt wird, indem di Schwankungen des Magnetfeldes mit dem Detektor erfaßt werden.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß die Magnetachse an verschiedenen Positionen über die Länge des Gegenstandes verschieden ausgerichtet ist.

3. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß das Magnetfeld über die Länge des Gegenstandes sich wiederholend schwankt, und daß der Detektor die sich wiederholenden Schwankungen des Magnetfeldes erfaßt.

4. Verfahren nach Anspruch 3, wobei der Gegenstand annähernd horizontal unterhalb der Erdoberfläche eingegraben ist, und **dadurch gekennzeichnet,** daß der Detektor über die Erdoberfläche in einer Linie annähernd parallel zur Länge des Gegenstandes bewegt wird, um die Lage des Gegenstandes aufzufinden.

5. Verfahren nach Anspruch 4, **dadurch gekennzeichnet,** daß die sich wiederholenden Schwankungen des Magnetfeldes eine R ihe von Magnetfeldspitzen und -tälern entlang der Linie er-

zeugen, die von dem Detektor erfaßt werden.

6. Verfahren nach Anspruch 5, **dadurch gekennzeichnet,** daß der Detektor von der Art ist, die entgegengesetzte Polaritätsanzeigen aufweist, die den Spitzen bzw. Tälern entsprechen.

7. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß sowohl horizontale als auch vertikale Komponenten des Magnetfeldes über die Länge des Gegenstandes sich wiederholend schwanken.

8. Verfahren nach Anspruch 7, **dadurch gekennzeichnet,** daß der Detektor sowohl die horizontalen als auch die vertikalen Komponenten erfaßt.

9. Verfahren nach Anspruch 8, **dadurch gekennzeichnet,** daß der Detektor eine Vektorsumme der horizontalen und vertikalen Komponenten bestimmt.

10. Verfahren nach Anspruch 8, **dadurch gekennzeichnet,** daß der Detektor eine Skalarsumme der horizontalen und vertikalen Komponenten bestimmt.

11. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß der Detektor ein Handgradiometer ist.

12. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß die Vorrichtung als Wendel mit einer Längsachse ausgeformt ist, die sich über die Länge des Gegenstandes erstreckt.

13. Verfahren nach Anspruch 12, **dadurch gekennzeichnet,** daß die Längssteigung der Wendel erheblich größer ist als die Querabmessungen der Wendel.

14. Verfahren nach Anspruch 13, **dadurch gekennzeichnet,** daß die Steigung in der Größenordnung von 3,66 m (12 Fuß) liegt.

15. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß die Vorrichtung so geformt ist, daß ihre Breitenabmessung erheblich größer ist als ihre Dickenabmessung und sie in der Richtung ihrer Breite magnetisiert ist.

16. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß das magnetische Material im wesentlichen nichtleitend ist.

17. Verfahren nach Anpruch 1, **dadurch gekennzeichnet,** daß der Gegenstand aus Kunststoff besteht.

18. V rfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß der Gegenstand als eine Röhre ausgeformt ist, wobei das magnetische Material in einer Wand der Röhre verteilt ist.

19. Verfahren nach Anspruch 1, **dadurch gekennzeichnet,** daß die Ausrichtung der Magnetachse in Bereichen, die über die Länge des Gegenstandes beabstandet sind, im wesentlichen vertikal ist, und eine vertikale Komponente des Magnetfeldes in den Bereichen in einem Grad abnimmt, der im wesentlichen geringer ist als die dritte Potenz des Abstandes zu dem Gegenstand in einer vertikalen Richtung.

20. Verfahren nach Anspruch 19, **dadurch gekennzeichnet,** daß der Grad im wesentlichen die zweite Potenz des Abstandes ist.

21. Längliche Magnetvorrichtung (10) zum magnetischen Ermitteln der Lage eines verborgenen länglichen, zylindrischen oder röhrenförmigen Gegenstandes (12), wobei die Vorrichtung magnetisches Material umfaßt, das in dem Gegenstand verteilt ist, **dadurch gekennzeichnet,** daß das magnetische Material quer zur Länge des Gegenstandes magnetisiert ist, so daß es eine Magnetachse quer zu seiner Länge aufweist, und so daß es ein Magnetfeld erzeugt, das über die Länge des Gegenstandes auf vorgegebene Weise sich wiederholend schwankt, wodurch eine charakteristische Magnetfeldzeichnung entsteht, die von einem Magnetfeldetektor (14) erfaßt werden kann, der über die Länge des Gegenstandes bewegt wird, wodurch die Lage des Gegenstandes ermittelt werden kann.

22. Längliche Magnetvorrichtung nach Anspruch 21, **dadurch gekennzeichnet,** daß die Ausrichtung der Magnetachse über die Länge des Gegenstandes sich wiederholend schwankt.

23. Längliche Magnetvorrichtung nach Anspruch 21, **dadurch gekennzeichnet,** daß das magnetisierte magnetische Material einen Streifen in Form einer länglichen Wendel bildet.

24. Längliche Magnetvorrichtung nach Anspruch 23, **dadurch gekennzeichnet,** daß der Streifen im wesentlichen nichtleitend ist.

25. Längliche Magnetvorrichtung nach Anspruch 23, **dadurch g kennzeichnet,** daß die Wendel eine Längssteigung aufweist, die erheblich größer ist als die Querabmessungen der Wendel.

26. Längliche Magnetvorrichtung nach Anspruch 25, **dadurch gekennzeichnet,** daß die Steigung in

der Größenordnung von 3,66 m (12 Fuß) li gt.

27. Längliche Magnetvorrichtung nach Anspruch 23, **dadurch gekennz ichn t,** daß die Breite des Streifens kleiner ist als die Breite des Geg nstandes.

28. Längliche Magnetvorrichtung nach Anspruch 23, **dadurch gekennzeichnet,** daß die Breite des Streifens der Breite des Gegenstandes entspricht.

29. Längliche Magnetvorrichtung nach Anspurch 21, **dadurch gekennzeichnet,** daß die Vorrichtung eine Vielzahl beabstandeter Streifen (16 oder 17) aus magnetischem Material umfaßt, wobei sich ihre Länge über die Länge des Gegenstandes erstreckt und sie quer zu ihrer Länge magnetisiert sind.

30. Längliche Magnetvorrichtung nach Anspruch 21, **dadurch gekennzeichnet,** daß die Vorrichtung eine Vielzahl beabstandeter Röhren (18 oder 20) aus magnetischem Material umfaßt, die koaxial zu dem Gegenstand sind und quer zu ihrer Länge magnetisiert sind.

31. Längliche Magnetvorrichtung nach Anspruch 21, **dadurch gekennzeichnet,** daß die Vorrichtung eine Vielzahl von Streifen (16 oder 17) aus magnetischem Material umfaßt, wobei sich ihre Länge über die Länge des Gegenstandes an in Umfangsrichtung beabstandeten Positionen an dem Gegenstand erstreckt und sie quer zu ihrer Länge magnetisiert sind.

32. Längliche Magnetvorrichtung nach Anspruch 31, **dadurch gekennzeichnet,** daß die Positionen auch in Längsrichtung auf dem Gegenstand beabstandet sind.

33. Längliche Magnetvorrichtung nach Anspruch 21, **dadurch gekennzeichnet,** daß die Vorrichtung eine Vielzahl von Röhren (18 oder 20) aus magnetischem Material umfaßt, die über die Länge des Gegenstandes beabstandet sind, und die kollineare Achsen parallel zur Länge des Gegenstandes haben, wobei jede Röhre eine Magnetachse quer zur Länge des Gegenstandes aufweist, und die Magnetachsen aufeinanderfolgender Röhren unterschiedliche Ausrichtungen haben.

34. Längliche Magnetvorrichtung nach Anspruch 33, **dadurch gekennzeichn t,** daß jede Röhre durch einen wendelförmigen Streifen (20) gebildet wird.

Revendications

1. Procédé de détection de la position d'un objet (12) cylindrique ou tubulaire, allongé, caché, dans lequel ledit objet est pourvu d'un dispositif à magnétisme permanent (10) allongé, dont la longueur s'étend dans la direction longitudinale dudit objet, ledit dispositif étant constitué de matériau magnétique, dispersé dans ledit objet et l'emplacement dudit objet étant détecté à l'aide d'un détecteur de champ magnétique (14), caractérisé en ce que le matériau magnétique est l'objet d'une magnétisation orientée dans la direction transversale dudit objet, pour constituer un axe magnétique transversal par rapport à la direction longitudinale dudit objet et pour constituer un champ magnétique variant de manière prédéterminée dans la longueur dudit objet, et en ce que l'emplacement dudit objet est détecté par la détection des variations dudit champ magnétique, appréhendée à l'aide dudit détecteur.

2. Procédé selon la revendication 1, caractérisé en ce que l'orientation dudit axe magnétique varie en différentes positions de la longueur dudit objet.

3. Procédé selon la revendication 1, caractérisé en ce que ledit champ magnétique varie de façon répétitive sur la longueur dudit objet, et ledit détecteur détecte les variations répetitives dudit champ magnétique.

4. Procédé selon la revendication 3, dans lequel ledit objet est caché à peu près horizontalement sous la surface du sol et caractérisé en ce que le détecteur est déplacé sur la surface du sol, sur une ligne à peu près parallèle à la direction longitudinale dudit objet, de manière à obtenir la trace de l'emplacement dudit objet.

5. Procédé selon la revendication 4, caractérisé en ce que les variations répétitives dudit champ magnétique produisent une série de crêtes et de vallées du champ magnétique, sur ladite ligne, ces crêtes et vallées étant détectées par ledit détecteur.

6. Procédé selon la revendication 5, caractérisé en ce que ledit détecteur est du type donnant des indications de polarités inverses correspondant respectivement auxdites crêtes et vallées.

7. Procédé selon la revendication 1, caractérisé en ce que les composantes horiz ntales ainsi que les composantes verticales dudit champ magnétique varient de façon répétitive sur la longueur dudit obj t.

8. Procédé selon la revendication 7, caractérisé en ce que ledit détecteur détecte à la fois lesdites composantes horizontales et verticales.

9. Procédé selon la revendication 8, caractérisé en ce que ledit détecteur effectue la somme vectorielle desdites composantes horizontales et verticales.

10. Procédé selon la revendication 8, caractérisé en ce que ledit détecteur effectue la somme scalaire desdites composantes horizontales et verticales.

11. Procédé selon la revendication 1, caractérisé en ce que ledit détecteur est un gradiomètre portatif.

12. Procédé selon la revendication 1, caractérisé en ce que ledit dispositif est réalisé en forme d'hélice, avec un axe longitudinal s'étendant dans la direction longitudinale dudit objet.

13. Procédé selon la revendication 12, caractérisé en ce que le pas longitudinal de ladite hélice est sensiblement supérieur aux dimensions transversales de ladite hélice.

14. Procédé selon la revendication 13, caractérisé en ce que ledit pas est de l'ordre de 3,66 m (12 pieds).

15. Procédé selon la revendication 1, caractérisé en ce que ledit dispositif est réalisé de façon à ce que sa largeur soit sensiblement supérieure à son épaisseur et est magnétisé dans la direction de sa largeur.

16. Procédé selon la revendication 1, caractérisé en ce que ledit matériau magnétique est pratiquement non-conducteur.

17. Procédé selon la revendication 1, caractérisé en ce que ledit objet est en matière plastique.

18. Procédé selon la revendication 1, caractérisé en ce que ledit objet est réalisé sous forme de tube, le matériau magnétique étant dispersé dans la paroi du tube.

19. Procédé selon la revendication 1, caractérisé en ce que l'orientation dudit axe magnétique est sensiblement verticale en des zones espacées sur la longueur dudit objet, et la composante verticale dudit champ magnétique, en lesdites zones, va en diminuant avec une tendance sensiblement inférieure à la puissance cubique de la distance par rapport audit obj t en direction verticale.

20. Procédé selon la revendication 19, caractérisé en ce que ladite tendance évolue sensiblement comme la puissance carrée de ladite distance.

21. Dispositif magnétique (10) allongé, pour la détection magnétique de l'emplacement d'un objet cylindrique ou tubulaire (12) allongé, caché, ledit dispositif comprenant un matériau magnétique dispersé dans ledit objet, caractérisé en ce que le matériau magnétique est l'objet d'une magnétisation orientée transversalement par rapport à la direction longitudinale de l'objet, de façon à av ir un axe magnétique transversal par rapport à sa direction longitudinale et à produire un champ magnétique variant de manière répétitive dans la longueur dudit objet, d'une manière prédéterminée, de manière à produire une signature de champ magnétique caractéristique, susceptible d'être détectée par un détecteur de champ magnétique (14) déplacé sur la longueur de l'objet, faisant que l'emplacement dudit objet peut être détecté.

22. Dispositif magnétique allongé selon la revendication 21, caractérisé en ce que l'orientation dudit axe magnétique varie de façon répétitive sur la longueur dudit objet.

23. Dispositif magnétique allongé selon la revendication 21, caractérisé en ce que le matériau magnétique magnétisé forme une bande ayant la forme d'une hélice allongée.

24. Dispositif magnétique allongé selon la revendication 23, caractérisé en ce que ladite bande est pratiquement non conductrice.

25. Dispositif magnétique allongé selon la revendication 23, caractérisé en ce que le pas longitudinal de ladite hélice est sensiblement supérieur aux dimensions transversales de ladite hélice.

26. Dispositif magnétique allongé selon la revendication 25, caractérisé en ce que ledit pas est de l'ordre de 3,66 m (12 pieds).

27. Dispositif magnétique allongé selon la revendication 23, caractérisé en ce que la largeur de ladite bande est inférieure à la largeur dudit objet.

28. Dispositif magnétique allongé selon la revendication 23, caractérisé en ce que la largeur de ladite bande correspond à la largeur dudit objet.

29. Dispositif magnétique allongé selon la revendication 21, caractérisé en ce que ledit dispositif c mprend une pluralité de bandes espacées (16 ou 17), en matériau magnétique, leur longueur

étant orientée dans la direction longitudinal dudit objet et leur magnétisation étant orientée dans la direction transversale par rapport à leur longueur.

30. Dispositif magnétique allongé selon la revendication 21, caractérisé en ce que ledit dispositif comprend une pluralité de tubes (18 ou 20) espacés, réalisée en un matériau magnétique, placés coaxialement par rapport à l'objet et magnétisés en direction transversale par rapport à leur direction longitudinale.

31. Dispositif magnétique allongé selon la revendication 21, caractérisé en ce que ledit dispositif comprend une pluralité de bandes (16 ou 17) en matériau magnétique, leur longueur étant orientée dans la direction longitudinale dudit objet, en des emplacements espacés circonférentiellement sur ledit objet et leur magnétisation étant orientée dans la direction transversale par rapport à leur longueur.

32. Dispositif magnétique allongé selon la revendication 31, caractérisé en ce que lesdits emplacements sont également espacés longitudinalement sur ledit objet.

33. Dispositif magnétique allongé selon la revendication 21, caractérisé en ce que ledit dispositif comprend une pluralité de tubes (18 ou 20) en matériau magnétique, espacés dans la direction longitudinale dudit objet et ayant des axes colinéaires, parallèles à la direction longitudinale dudit objet, chaque tube ayant un axe magnétique transversal par rapport à la direction longitudinale dudit objet, et les axes magnétiques des tubes successifs ayant des orientations différentes.

34. Dispositif magnétique allongé selon la revendication 33, caractérisé en ce que chaque tube est défini par une bande hélicoïdale (20).

FIG. 1

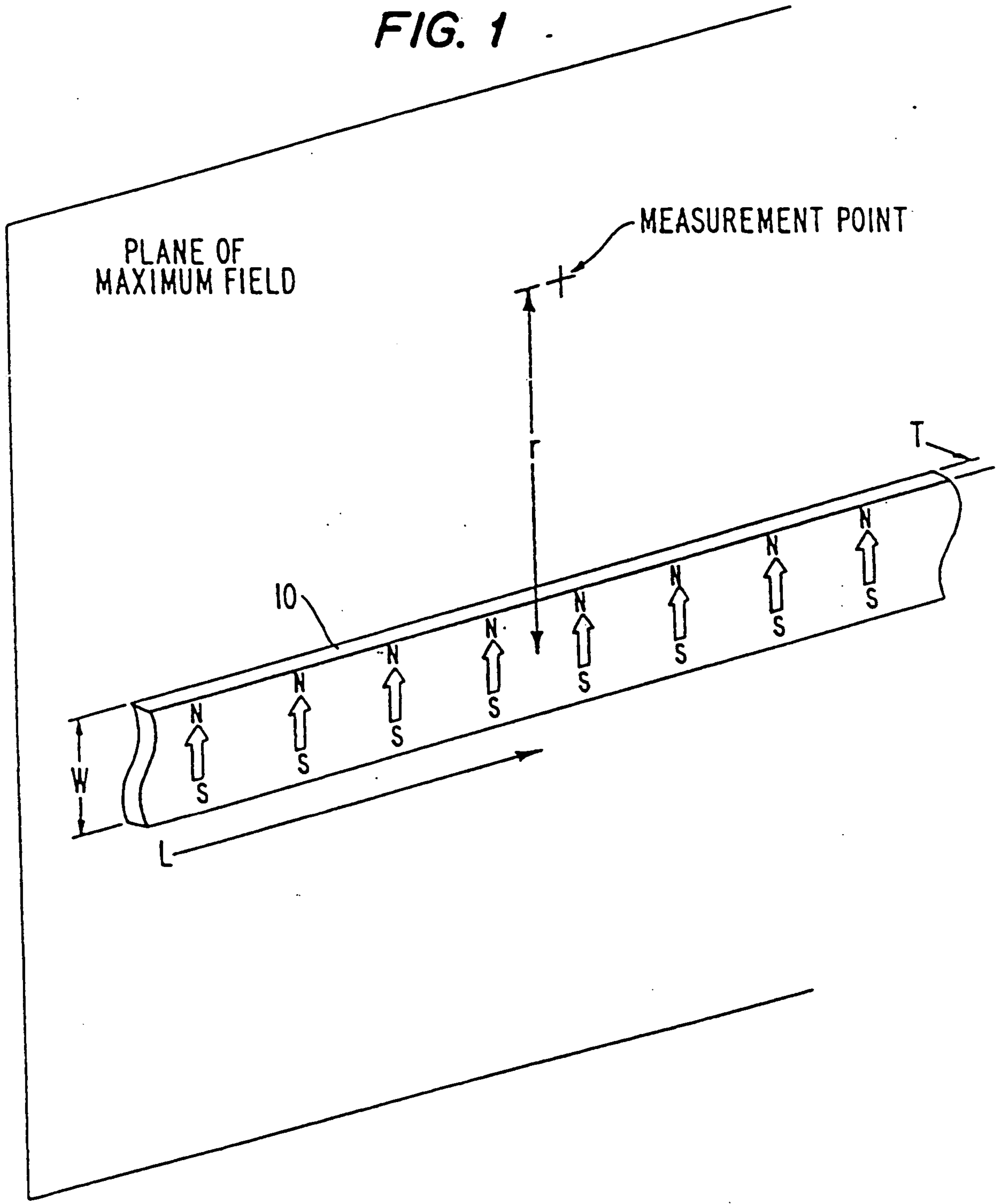

FIG. 2

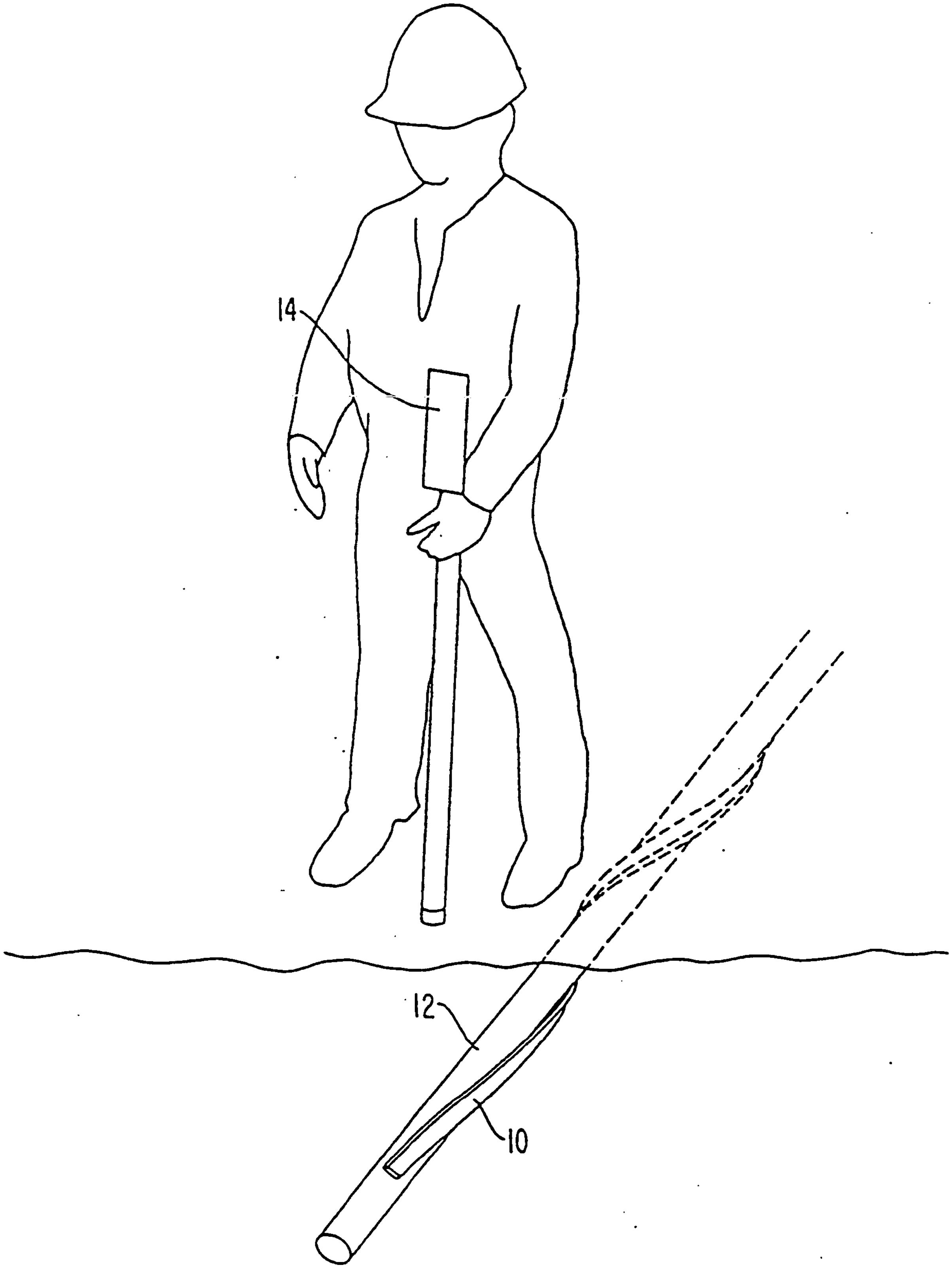

FIG. 3A

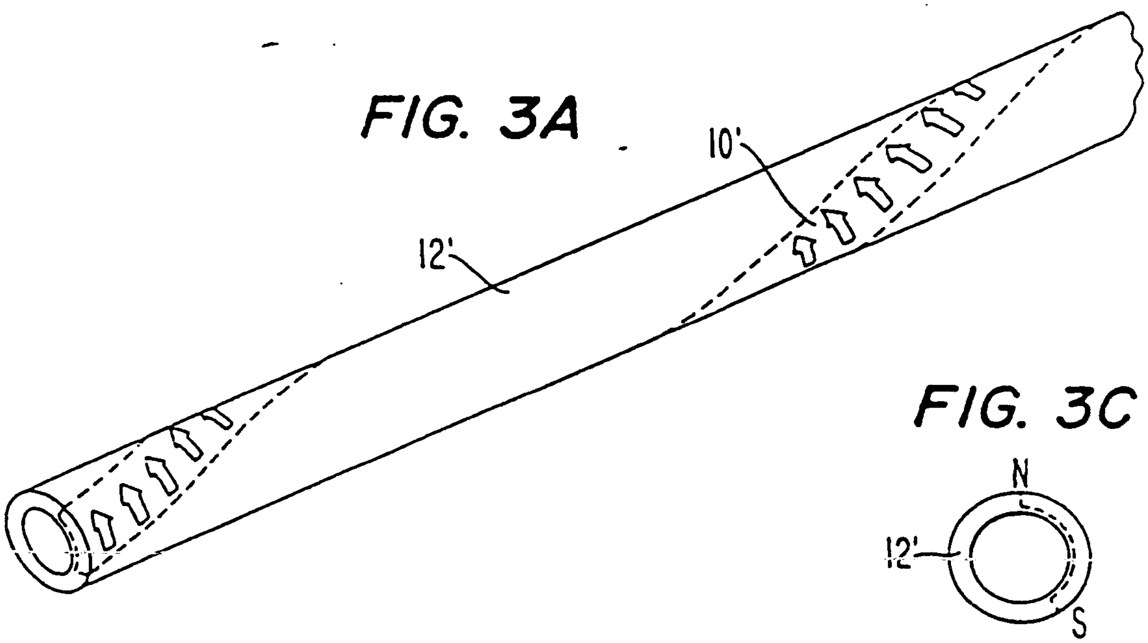

FIG. 3C

FIG. 3B

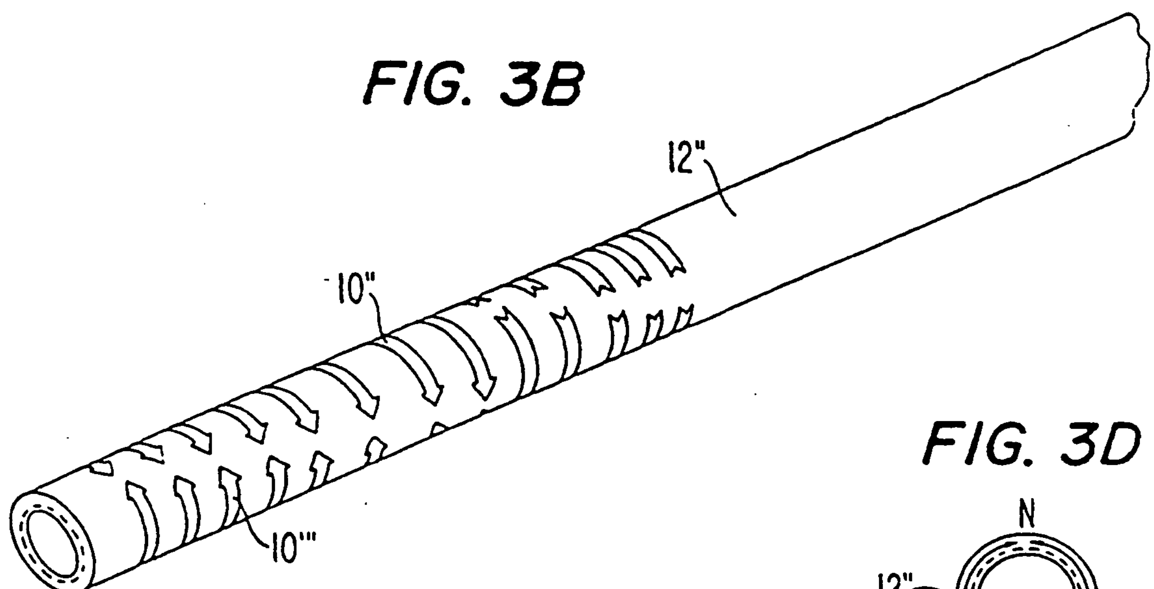

FIG. 3D

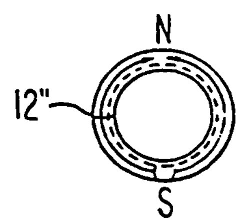

FIG. 4

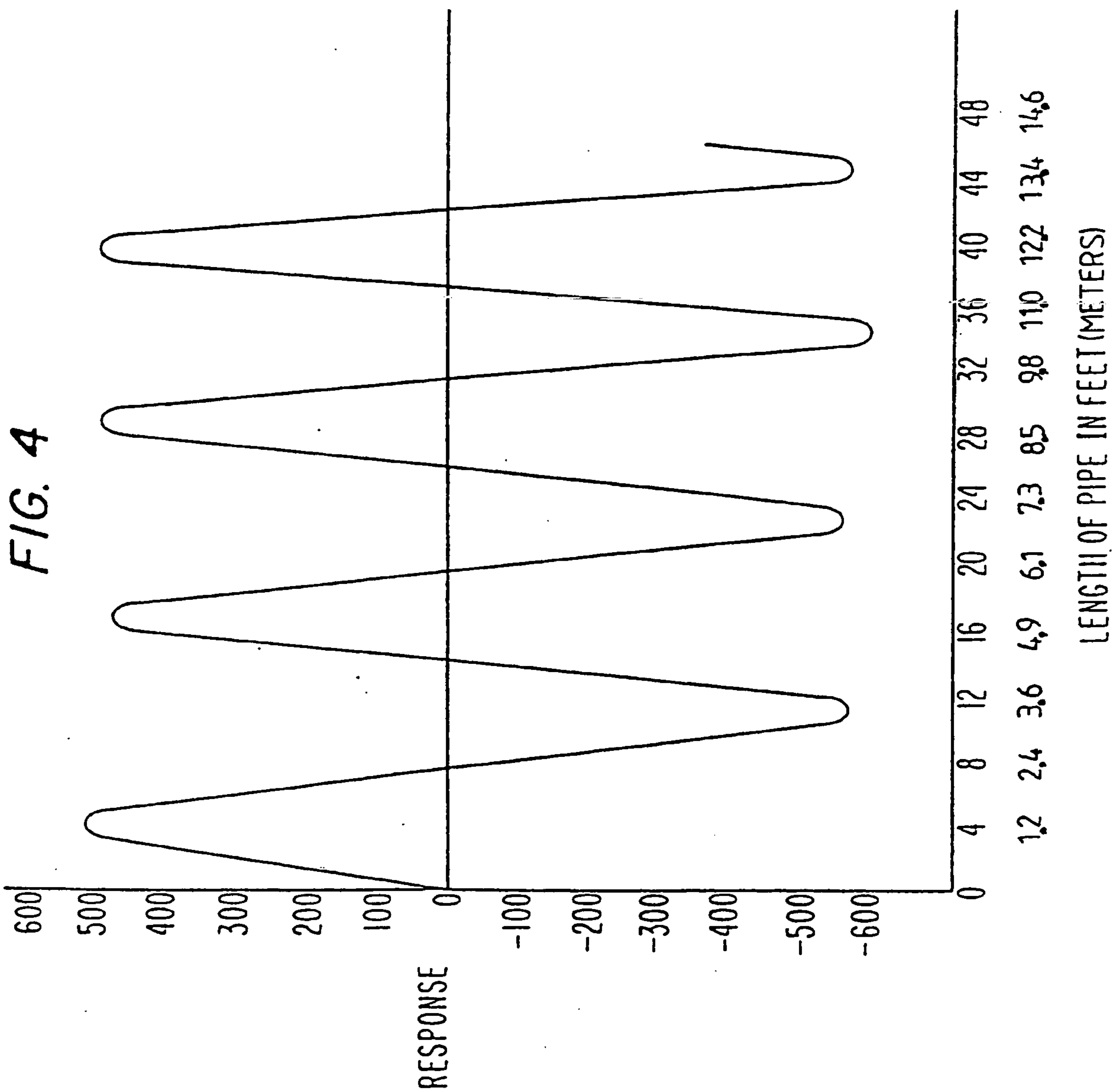
RESPONSE
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
0
4
8
12
16
20
24
28
32
36
40
44
48
1,2
2,4
3,6
4,9
6,1
7,3
8,5
9,8
11,0
12,2
13,4
14,6
LENGTH OF PIPE IN FEET (METERS)

FIG. 5

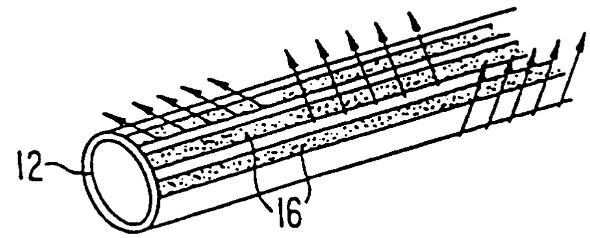

FIG. 6

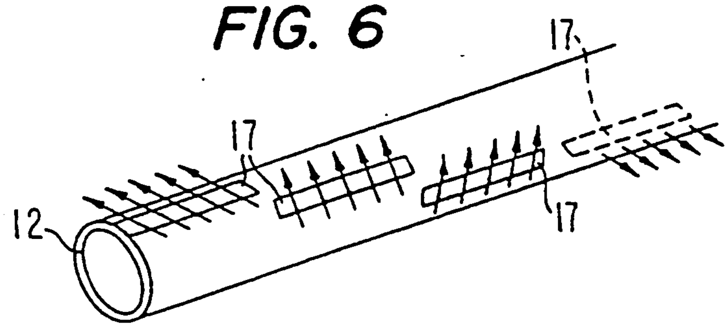

FIG. 7

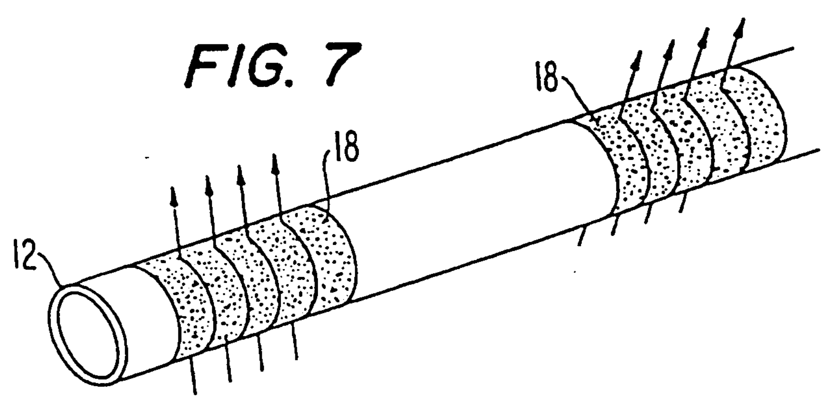

FIG. 8

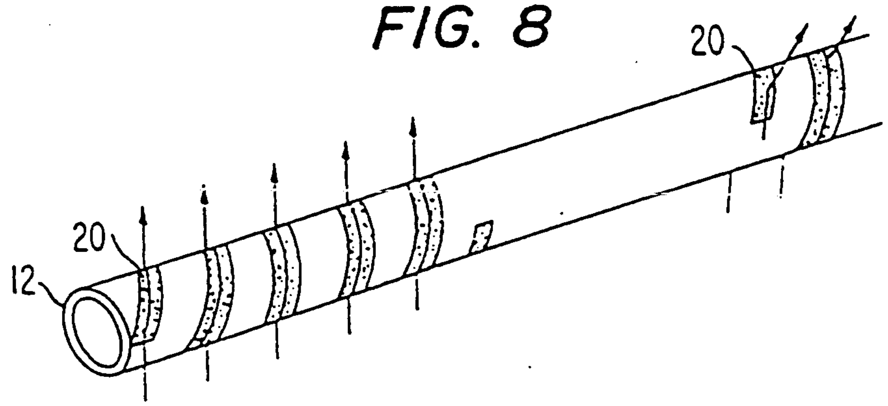

FIG. 9